Front Resolving Observational Network with Telemetry: Turbulence Characterization from an AUV

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Document Number: N0001401WX20577
http://www.sp.uconn.edu/~wwwmsd/nopp_pgm/noppprop.html

LONG-TERM GOALS

A Front-Resolving Observational Network with Telemetry (FRONT) is being developed for a region of the coastal ocean. The long-term goal is to demonstrate and evaluate a real-time data collection network in concert with a data-assimilative dynamical model, which is designed to resolve or parameterize the needed range of scales, from mesoscales to microscales.

OBJECTIVES

The lack of observations of vertical mixing imposes a severe limitation on modeling of coastal mixing processes near dynamic features such as fronts. The specific objectives of the AUV-based turbulence characterization component of this network are to evaluate the system on the microstructure scale.

APPROACH

The FRONT system includes data-assimilative models that mitigate the impact of sampling error by producing dynamically consistent maps from the data, enabling physical and biological forecasting in four dimensions (Bogden and O'Donnell, 1998). The multi-disciplinary demonstration site lies in a region of strongly varying bathymetry offshore of Long Island Sound, out to the 50m isobath. Tides and energetic wind and buoyancy forced motions combine to produce a complex flow field. Satellite measurements of surface temperature and color show recurrent front-like features at the FRONT site (Ullman and Cornillon, 1999).

The FRONT network is evaluated in repeated, five day, rapid, high-resolution, surveys of hydrography, circulation, and microstructure. Information is obtained on scales of turbulent dissipation, frontal scales, and mesoscales. The turbulence surveys should improve frontal behavior in the model, based on the MIT general circulation model (MITgcm) (i.e., Marshall et al., 1997), adapted to the coastal ocean for FRONT. The non-hydrostatic capability is important for the strong convergence/divergence of fronts, and in large aspect ratio flows near topography. MITgcm includes the Large et al. (1994) nonlocal "K profile parameterization" (KPP) of vertical mixing.

The microstructure instrument (Levine et al, 1999) is a modified REMUS AUV with: 1) shear sensors for turbulent kinetic energy dissipation rates, 2) an ultra-fast thermistor for thermal dissipation rates, and 3) an Acoustic Doppler Velocimeter for 3D velocity. In addition, the AUV has two CTDs, and an

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Front Resolving Observational Network with Telemetry: Turbulence Characterization from an AUV**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Undersea Warfare Center, Division Newport,,Code 8211, Bldg 679/2,,Newport,,RI,02841**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

up/down looking ADCP. The shear probe data are processed to remove noise associated with vehicle vibrations, using accelerometers, and the techniques of Levine and Lueck (1999). In addition to microstructure, these sensors provide stratification and finescale shear, enabling estimation of Richardson number, eddy diffusivity (Gargett and Moum,1995), eddy viscosity (truncated TKE equation), fluxes (correlation technique) and turbulent kinetic energy. This provides a direct comparison between co-located measurements of microstructure and larger scales, critical to develop bulk representations of microscale processes. The AUV will be deployed with the MicroSoar (URI), which uses a rugged conductivity probe to resolve the thermal dissipation rate. In close proximity, they will allow turbulence data to be collected for correlations of mixing processes. Previously, this was done using ships several miles apart (Moum et al., 1994).

WORK COMPLETED

A modified REMUS AUV has been integrated with a comprehensive instrument suite for measuring turbulence in the coastal ocean, including the terms in the truncated TKE equation. The noise floor of the dissipation estimate has been lowered to 10^{-9} W/kg, using vibration analysis techniques. This resulted in the fabrication and installation of an aluminum 3-probe stiffener, which shortens the probe cantilever, and raises the shear probe resonance frequency into the kilohertz range. In addition, the AUV, itself, has been modified for deployment and recovery from a large research vessel in the open waters of the mid-shelf.

During fall and spring 2000 and 2001, using the improved AUV-based turbulence measurement system, a mixing studies was conducted in the FRONT region, in the context of supporting frontal scale observations, including shipboard ADCP and CTD, and moored ADCP. Turbulence data were obtained in upper ocean fronts offshore of Long island Sound, in the region of maximum near surface salinity gradient, as determined from profiling and hull mounted CTD data. In addition, a brief study of the intense front associated with the Connecticut River plume, an upstream condition for the main study, was also completed.

RESULTS

Fronts Offshore of Long Island Sound

Results from the fall and spring surveys in 2000 (FRONT 2) and the fall survey in 2001 (FRONT 3) indicate low levels of turbulent velocity shear and thermal microstructure encountered in the region offshore of the front, east of the Montauk buoy. Correspondingly, low dissipation rates (ε) of 10^{-9} to 10^{-8} W/kg were estimated for this trajectory. In this region, low values of both eddy diffusivities of 10^{-7} m^2/s, and eddy viscosities of 10^{-7} m^2/s are estimated. Also, in the frontal region, east of Montauk, the Richardson number is estimated to be intermediate, 10^0. These estimates indicate that the frontal region was weakly turbulent. The nature of the turbulent processes can be examined by constructing a buoyancy Reynolds number versus Froude number scatterplot of the data. For this frontal region, the data lie in the region of bouyancy dominated turbulence, where the buoyancy Reynolds number is lower than a value of 20. The low kinetic energy dissipation estimates in these datasets persist throughout the region offshore of the tidal mixing front location, consistent with the MITgcm model (Fig. 1).

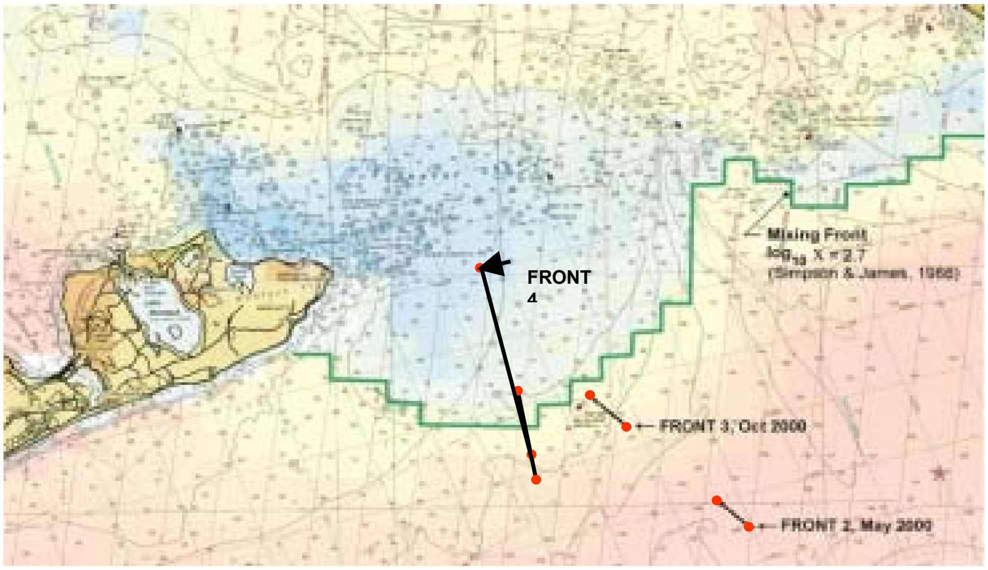

Fig. 1 Map of FRONT study region of L. I. Sound with location of tidal mixing front indicated. The black lines are AUV trajectories

Results from the spring survey in 2001 (to the SW of the previous line closer to Montauk, further inshore, FRONT 4) indicate that high levels of turbulent velocity shear and thermal microstructure are encountered in the region inshore of the front and in the transition through the front. Correspondingly, high dissipation rates (ε) of 10^{-7} to 10^{-6} W/kg were estimated for this trajectory. In this region, high values of both eddy diffusivities of 10^{-5} m^2/s, and eddy viscosities of 10^{-3} m^2/s are estimated. The data enable an estimate of the thermal dissipation rate (λ), 10^{-8} to 1×10^{-7} $(°C)^2/s$, and the mixing efficiency (γ), 10^{-2} to 10^{-1} near the front (Fig. 2). Also, in the frontal region, the Richardson number is estimated to be low, 10^{-1} to 10^{0}.

These estimates indicate that the frontal region was strongly turbulent. The buoyancy Reynolds number versus Froude number scatterplot was done for this frontal region (Gargett et al, 1984). The data lie in the region of isotropic turbulence, where the buoyancy Reynolds number exceeds a value of 200. The high kinetic energy dissipation estimates persist from the inshore region near Monauk Pt. across the tidal mixing front location predicted from a version of the MITgcm, which includes only tides, bathymetry, and bottom mixing. The spatial distribution of the thermal dissipation and mixing efficiency will be investigated in relation to the front. Also, versions of the model which include additional physics will be utilized in this effort.

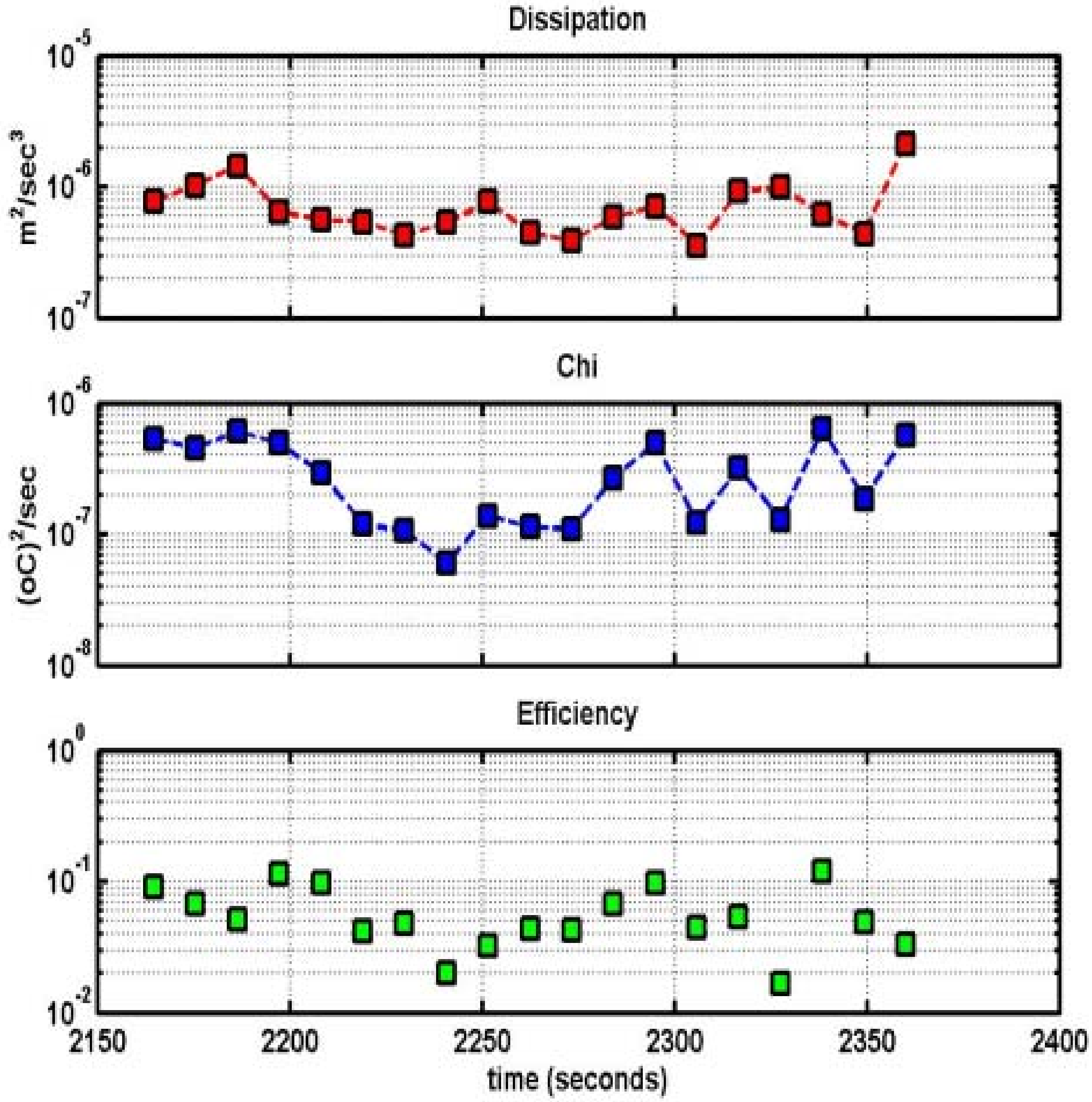

Fig. 2 Mixing parameters from the region of the predicted tidal mixing front from FRONT 4

Connecticut River Plume Front

Results from the April 2000 survey indicate that very high levels of turbulent velocity shear and thermal microstructure are encountered in the transition through the plume front. Correspondingly, very high dissipation rates (ε) of 10^{-6} to 10^{-5} W/kg were estimated in the frontal region. In this region, high values of both eddy diffusivities of 10^{-4} to 10^{-3} m^2/s, and eddy viscosities of 10^{-4} to $1x10^{-2}$ m^2/s are estimated. Also, in the frontal region the Richardson number is estimated to be low, 10^{-1} to 10^{0}. These estimates indicate that the frontal region was strongly turbulent, and dominated by finescale shear. The buoyancy Reynolds number versus Froude number scatterplot was done for the plume front. The majority of the data lie in the region of isotropic turbulence, where the buoyancy Reynolds number exceeds a value of 200. The cross front scale of the enhanced turbulence in the data is approximately 50 m, previously untested in the field, and in agreement with the model predictions of O'Donnell et al (1998).

IMPACT/APPLICATIONS

The AUV-based turbulence measurements provide a unique horizontal profiling view of the variability of the mixing environment that cannot be obtained by more conventionally sampling measurements, and this approach can be further exploited in yo-yoed horizontal sections. These techniques are invaluable in frontal process studies utilizing the coastal version of the MITgcm model.

TRANSITIONS

This research demonstrates an Autonomous Ocean Sampling Network (AOSN) in the context of an Integrated Coastal Observing System in a region with tactically significant features. This is a prototype demonstration, which can be extrapolated to an environmental description of the Battlespace for superiority in ASW and MCM.

RELATED PROJECTS

My AUV-based turbulence measurement system has also been utilized in NOPP/ONR studies with the Rutgers University led LEO and Harvard University led LOOPS projects.

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